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Innovations for Navigation Projects Research Program

Demonstration of Onsite Wireless Control of Lock Operating Machinery

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Foreword

This report was prepared for Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Innovations for Navigation Projects (INP) Research Program. The study was conducted under Work Unit 33125 “Lock Gate Operating Controls and Equipment” managed at the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS.

Dr. Tony C. Liu was the INP Coordinator at the Directorate of Research and Development, HQUSACE. Mr. Don Dressler, HQUSACE, was the Research Area Coordinator. Dr. Reed L. Mosher, ERDC Structures Laboratory (SL), was the Laboratory Manager for the INP Program; Dr. Stan Woodson, ERDC, was the INP Program Manager.

The work was performed by the Materials and Structures Branch (CF-M), Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The Principal Investigator was Dr. L.D. Stephenson. The HQUSACE Technical Monitor was Dan Casapulla (CECW-EE). Special appreciation is extended to Barkley Lock personnel Gerald Cunningham, Lockmaster, and Jerry Wisdom, Electrician; to Nashville District Mechanical Engineer, Richard Nimmo; and to Wayne Lanier, Operations Manager, West Kentucky Area, for their assistance with this project. Mark Slaughter was the Acting Chief of CF-M. L. Michael Golish was the Chief of CF. Dr. Paul A. Howdyshell was the Acting Technical Director of the Facility Acquisition and Revitalization business area. The Acting Director of CERL was Dr. Alan Moore.

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1 Introduction

Background

Most of the single locks in the United States, constructed since the 1930s, have their lock operating controls in two small structures on top of the lock walls. One control station is near the upper gate recess and the other is near the lower gate recess. As described in Engineer Technical Letter (ETL) 1110-2-553, 30 May 1997, "Control Stations and Control Systems for Navigation Locks and Dams," this type of operation is referred to as local control since the controls are located adjacent to the lock gate to be operated. Some older single locks have four local control stations, two on each wall near the gate recesses.

Some locks use a central control station, which is in the operations building located on or adjacent to one of the lock walls and just downstream from the dam embankment. All lock gates and culvert valves are controlled from this central control station.

Most locks also have auxiliary operating positions referred to as local control points. The five new single locks in the Red River Waterway in Louisiana (U.S. Army Engineer District, Vicksburg) have a central control station and two portable local control points with pedestal mountings on the lock wall. These pedestal-mounted controls can be removed when the walls are overtopped by floodwaters. The Melvin Price Locks and Dam (St. Louis District) has a 110-ft-wide by 1,200-ft-long lock and a 110-ft-wide by 600-ft-long auxiliary lock separated by two dam spillway bays. The single centralized control station is housed high above the service bridge, with eight local control points provided at the four corners of the two separated locks for local operation during maintenance activities and emergency situations. Typically the local control rooms are fully enclosed. Both the centralized control stations and the local control rooms generally provide adequate lock control capabilities. It is preferable to conduct most lockage operations from the normal control rooms where the lock operator has access to all controls and communication systems such as marine radios, telephones, intercoms, etc. At times it may be desirable to operate certain equipment such as a tow haulage system, from outside locations on the lock wall, especially when needed to obtain a better visual operation from a safety standpoint.

Objective

The objective of this work unit was to demonstrate onsite wireless command, control, and monitoring of lock operating equipment during standard lock operations and during maintenance procedures.

Approach

To investigate and evaluate the concept of onsite wireless control, the Construction Engineering Research Laboratory (CERL) collaborated with the operations engineers and Barkley Lock and Dam staff at the Nashville District to develop the requirements and specifications for two types of onsite wireless control systems:

1. a mobile control/feedback wireless system that could be transported on a Cushman Minute-Miser cart (Cushman Textron, Augusta, GA)
2. a handheld wireless control system that could easily be carried by lock operators and maintenance personnel.

The mobile system consisted of a wireless modem (manufactured by Data-Linc Group, Redmond, WA) interfaced to an operator interface (OI) called the Panel-Mate Plus (manufactured by Modicon, Palatine, IL). The Data-Linc modem was selected because it is operationally compatible with the programmable logic controllers (PLCs) manufactured by Square D (Palatine, IL), which are used at Barkley Lock and Dam.

The platform for the handheld wireless control system was a small portable transmitter provided by Remtron Corp. (Escondido, CA) that is compatible with both PLC-based and relay-based control systems.

Mode of Technology Transfer

It is recommended that the information and guidelines presented in this report be included in the applicable Unified Facilities Guide Specifications (UFGS), and field operation manuals for navigation locks.

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for the International System of units (SI) is provided below.

SI conversion factors		
1 in.	=	2.54 cm
1 ft	=	0.305 m
1 lb	=	0.453 kg

2 Cart-Mounted Wireless Control System Using Modem and Touchscreen Panel

Barkley Lock is 800-ft long x 110-ft wide with a 57-ft lift. The vertical viewing distance is approximately 80 ft. Normally, Barkley Lock has only one operator on duty per shift, and has operated this way for the past 30 years.

CERL and Barkley Lock and Dam personnel began discussing the implementation of onsite wireless control at the Lock and Dam for control of their tow-haulage unit in December 1998. At that time, a small, lightweight control panel with pressure control pads and light-emitting diode (LED) display (the Modicon PanelMate Plus shown in Figure 1) was being used to monitor the head water, tail water, and chamber water levels.



Figure 1. Closeup view of Modicon PanelMate operator interface.

The PanelMate was also being used to control the tow-haulage machinery (Figure 2) on the lock wall from inside the local control room. The tow-haulage procedure requires deck hands on the vessel and barge to tie a line to the towing kevil that is pulled along a track along the lock wall. Once the tow is secure, a deck hand or the captain signals to the lock operator to initiate the towing process. However, tow haulage also requires the operators to leave the existing control stand in order to maintain visual contact and monitor the tow-hauling process in order to prevent accidents. For example, the tow line must be kept taut to prevent the tow from traveling too quickly, getting ahead of the kevil, and pulling against it. This could result in the tow line snapping, or the kevil being pulled off its track. Thus, control of tow haulage along the lock wall significantly reduces the chances for such incidents to occur.

A wireless control system that permits the operator to control and monitor the tow-haulage equipment, while providing the operator with a direct view from along the lock wall, appeared to be the answer to this problem. It was decided that optimum onsite wireless control of the tow haulage system could be achieved through the use of the touchscreen control OI in conjunction with a wireless modem, which would enable the transmission of control commands directly to the PLC.



Figure 2. Tow-haulage unit at Barkley Lock and Dam.

The wireless modem also enables transmission of relevant lock information data, such as tow haulage kevil speed and position, directly from the PLCs to the touchscreen OI and display panel. The wireless system configuration that uses the PanelMate control unit and the Data-Linc modem is intended to be an alternate means of operating the tow haulage system during normal operating conditions.

Since lock personnel travel from one end of the lock to the other on Cushman carts, it was decided to mount the wireless modems and control/display panel OI on the carts. The carts' 12-volt batteries would provide the necessary power. Procurement of the modems began in March 1999. Wireless Data-Linc modems were procured because they were electronically compatible with the Modicon PanelMate and the Square D PLCs. During July 1999, Data-Linc modems were interfaced to the PLCs and PanelMate OI units. Specifically, one Data-Linc modem operating in master configuration was interfaced to the Modicon PanelMate, and both were mounted onto a Cushman Minute-Miser cart. The second Data-Linc modem, operating in a slave configuration, was interfaced to the SY/MAX 8030 Central Processing Unit (CPU) of the PLC with an SPE-4 port-expander. The standard 12-volt battery that powers the Cushman cart provided power for both the modem and the PanelMate.

Appendix A shows a schematic diagram of the Data-Linc modem/PanelMate on-site wireless control system. Figure 3 shows the inverter that converts the battery-supplied 12-volt direct current (12VDC) into the alternating current (AC) signal required for operation of both devices. The OI control program has been

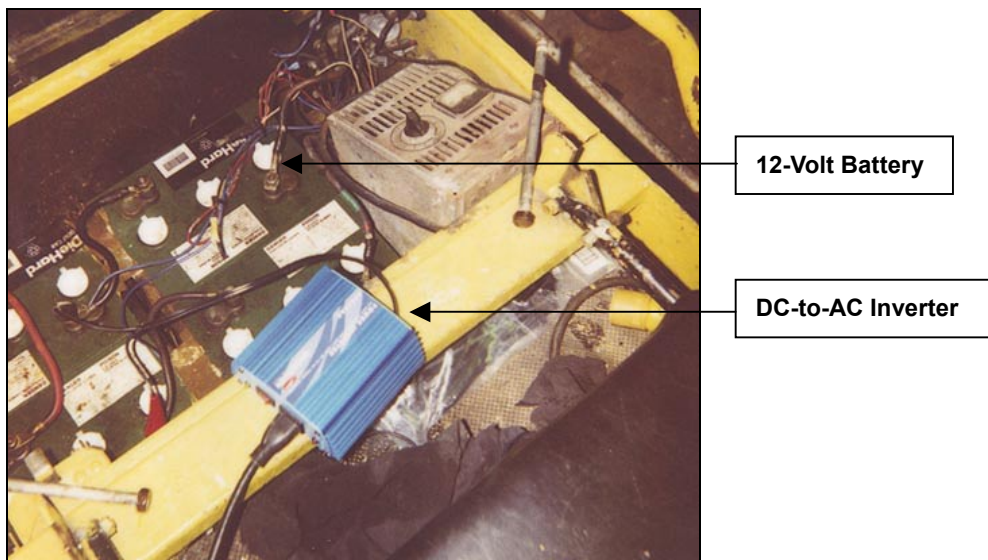


Figure 3. Battery and DC-to-AC inverter for the Modicon PanelMate and Data-Linc modem on the Cushman cart.

loaded into the PanelMate processing unit shown in Figures 1 and 4. Figure 4 also shows a view of the “master” Data-Linc modem physically mounted to the custom-designed housing for the PanelMate touch screen OI. Figure 5 shows the “slave” Data-Linc modem in the main building at Barkley Lock, which was directly connected to the Square D PLC CPU SY/MAX with the SPE-4 port expander. Figure 6 shows a modem and PanelMate mounted to one of the Cushman carts.

The full range of control capability and feedback information that is available via the wired PanelMate OIs in the control stations is also available through the wireless PanelMate control units mounted on the Cushman carts. The PanelMate provides control through touchpads on the unit, and the PanelMate screen continuously displays the feedback information transmitted from the PLCs. This data includes tow haulage speeds and positions, water levels, and filling and emptying valve status. In fact, any information that can be processed through the PLC can be displayed on the PanelMate. After 1 year of developing and refining the onsite wireless control/feedback system, Nashville District and Barkley Lock personnel have validated that, for tow haulage control, lock operators are in a better position to manage lockage events outside along the lock wall than when they are inside the control stations. Onsite wireless operation along the lock wall, therefore, appears to provide a safer mode of tow haulage operations. In certain instances, there could also be a need to operate other equipment such as miter gates and culvert valves from an outside portable station. Such operations should be reviewed carefully from a safety standpoint, however, factoring in the amount of information and format required to perform a safe operation. This can vary significantly from lock to lock due to differences in design and operation. Onsite wireless control has the potential of providing lock machinery control from any point along the long wall, including terminating the operations if any unsafe condition warrants it. Procurement specifications for the Modicon PanelMate OI and the Data-Linc wireless modem are given in Appendices B and C, respectively. Other systems such as Square-D’s Magelis Operator Interface line and Locus Modems are being prototyped for use with the Quantum PLC system upgrade now in progress at Barkley Lock.

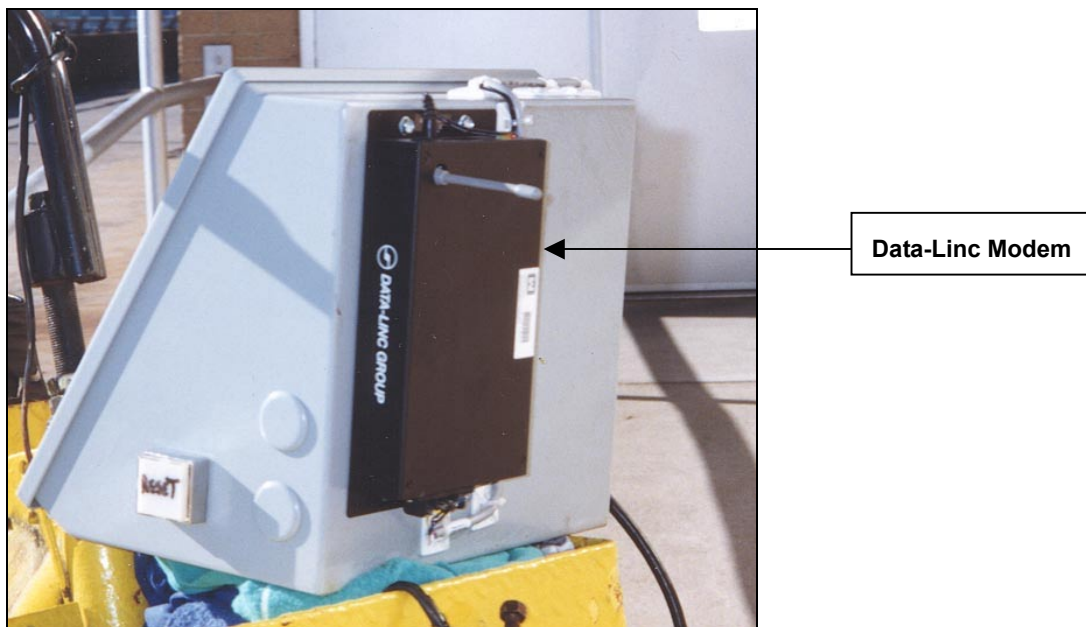


Figure 4. Data-Linc wireless modem mounted to the rear of the PanelMate custom-designed housing.



Figure 5. Data-Linc wireless receiver/transmitter in the central control building.



Figure 6. Demonstration of onsite wireless control at Barkley Lock and Dam using wireless modem and touchscreen OI mounted on a Cushman Minute-Miser cart.

3 Demonstration of a Handheld Wireless Control System for Maintenance Activities

During maintenance activities, the lock operating equipment data feedback and extended range of operation provided by the PanelMate and wireless modem system will generally not be necessary. During most maintenance situations, the operator is close to the equipment to be controlled. What an operator does need is the ability to start and stop equipment intermittently. This process is cumbersome if the operator must relay the desired controls to another operator in the control booth. In addition, there is an added element of danger for the maintenance technician who is working on a piece of equipment that could be accidentally activated by someone in the control booth several hundred feet away. A handheld remote controller designed to control a particular piece of equipment would provide the necessary control for such operations. This concept motivated researchers at CERL and personnel from the Nashville District to evaluate the Remtron radio system for use in maintenance activities.

Figure 7 shows the portable handheld transmitter (Remtron Command Pro Model 21T23), which weighs about 2 pounds, and operates on three AA batteries. The Remtron receiver may be mounted at some central location (e.g., in the equipment room or gallery). This system does not feed back lock data information (i.e., it provides the operator with control only and is similar to the operation of most television remote controllers in the home). When maintenance personnel are performing activities in cramped spaces (where a Cushman cart cannot go), they can operate gates and tainter valves via wireless control. A schematic diagram of the Remtron control system is shown in Appendix D.

Barkley Lock personnel have made the versatile and portable system shown in Figure 8 by installing the Remtron radio receiver 21R22 into a cabinet on rollers and interfacing it with a PLC processor.



Figure 7. Remtron handheld controller.

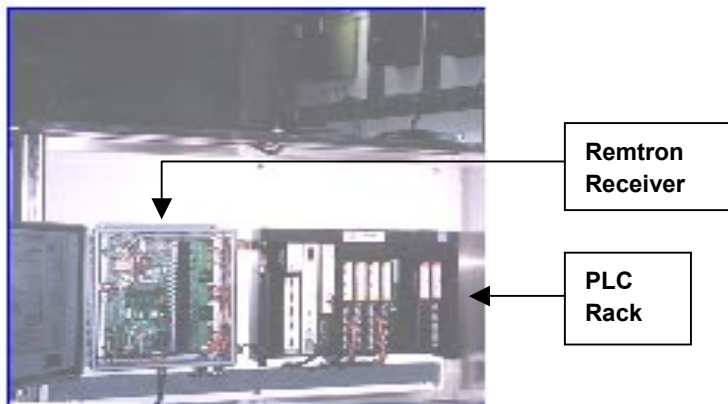


Figure 8. Mobile cabinet containing PLC rack interfaced to Remtron receiver.

The receiver's relay contacts are wired to PLC input cards that communicate with the PLC processor, which in turn communicates with the PLC output cards to start or stop machinery or electronic equipment. The receiver can receive commands from the handheld transmitter and instruct the PLC's output cards to activate and de-activate equipment on command. The cabinet enclosure can be easily transported within a lock's gallery and connected to the main terminal strips. The Remtron transmitter can be used to control equipment inside the gallery area during maintenance operations as long as the operating equipment is within 800 feet of the receiver.

The relays in the receiver are designed to provide a "momentary" signal, which translates into the proper input to a PLC input card. The ON/OFF signals and Select function "Upstream" or "Downstream" buttons (see Figure 9) are "latching" signals. The receiver also has the option of being configured to provide

latching signals compatible with conventional relay-based systems as indicated by the schematic diagram of the Remtron wireless control system in Appendix D. This system, therefore, may be used at locks where equipment is controlled through either conventional relays or PLCs.

The Remtron wireless control system is versatile. The receiver is equipped with 22 discrete relay switches. One switch is latching (the ON/OFF switch control) while the other switches are momentary, and may be interfaced to lock component relays or PLC input/output (I/O) cards. The portable 21T23 transmitter controls are rocker-arm type switches that operate gates, valves, pumps on river or land sides, and traffic signals, as shown on the faceplate in Figure 9. The transmitter also contains a “2nd” function switch. By pressing this switch and then the gate or valve switch, the speed of the gate or valve opening or closing may be controlled (e.g., increased from slow to fast). The slower speed may be restored upon pressing the rocker switch for the named function.

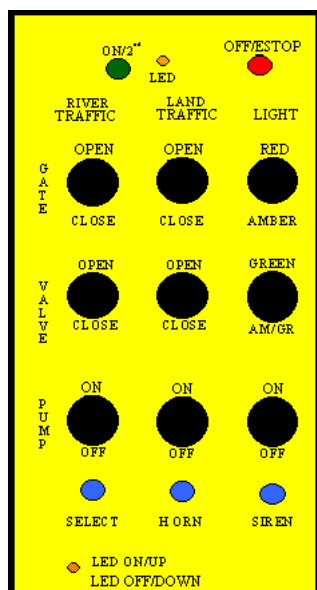


Figure 9. Diagram of the Remtron controller faceplate.

The specific details of the implementation of the 2nd function option are left to the lock electricians or qualified engineers who choose to use this system. The 2nd function could be used, for example, to select control options for the tow-haulage system.

Another feature worth noting is the RAC16 programmer that is included with the Remtron wireless control system. Although the transmitter and receiver are fully programmed and tested before being shipped from the factory, the RAC16 programmer enables the end user to reprogram the system for any operating

frequency, address code, and certain adjustable operating parameters that the particular system may require. Among the parameters that can be reprogrammed are the operating frequency and address of the unit, the time constants for functions, relay assignments, and the decoding of control logic.

Some limitations are associated with the Remtron wireless control system, but they are not an issue for the Data-Linc/PanelMate system. Though the size of the Remtron transmitter makes it convenient and portable, it limits the unit's power capacity (three AA batteries). This limited capacity confines the range of nominal operation to about 800 feet, and transmitter and receiver must be positioned within "line of sight" of each other. Thus, the Remtron wireless control system is limited to fairly short-range operations or control, but cannot be used in situations where the signal must be transmitted from the lock wall down to the gallery area. The Remtron system is useful for maintenance operations within the lock's gallery when the receiver is positioned there. The prototype handheld transmitter was configured to provide operational control for almost every system necessary to operate at the demonstration site, Barkley Lock. Control capability for the hydraulic pumps, operation of upper and lower miter gates and culvert valves, air horns, discharge warning lights, and even traffic signals is provided. From a practical maintenance standpoint, to ensure movement of only the desired piece of equipment, it may be safer to limit the number of systems or pieces of equipment to be controllable at any one time from a single handheld remote, especially considering the lack of feedback. Functioning of existing hard-wired safety interlocks and meeting requirements of lock-out, tag-out regulations during maintenance must also be factored in. Procurement specifications for the Remtron system are provided in Appendix E. Table 1 summarizes cost and functional information for both the Data-Linc/PanelMate control system and the Remtron system. See Appendix F for further comments on wireless command, control, and monitoring of lock equipment.

Table 1. Cost and functional comparison of the Data-Linc modem and Modicon PanelMate.

Feature	Remtron Wireless Control System	Data-Linc Modem and Modicon PanelMate
Cost	\$5000	\$3600
Feedback (display of equipment status)	No	Yes
Required Power	3 AA batteries	12 VDC, 150 amp-hr storage battery
Portability	Hand-held	Can be transported on Cushman cart
Compatible with Square-D PLC-based control systems	Yes	Yes
Compatible with relay-based control systems	Yes	No
Effective Range	800 ft	Up to 20 miles
Interface Versatility	Can interface via PLC I/O cards <i>or</i> directly to relays	Must interface through PLCs

4 Conclusions

Onsite wireless control of locks was demonstrated at Barkley Lock and Dam using two different configurations: (1) a mobile control/feedback system mounted on a Cushman cart that can also display relevant data and information related to lock operating machinery in real-time to the lock operator and (2) a handheld wireless control system (without feedback capabilities) that can be hand carried easily by lock personnel.

The cart-mounted system using a wireless modem and touchscreen OI was demonstrated to be a viable lock control alternative. It provides lock operators with the additional capability of controlling and monitoring lockage anywhere along the lock walls. The touchscreen OI can be configured to display to the lock operators relevant lock operation parameters, such as water level, gate positions and speeds, and valve positions and speeds. This system is especially useful for controlling and monitoring tow-haulage operations.

The wireless handheld transmitter control system has proven to be a flexible and convenient option for lock control during maintenance operations. The Remtron receiver may be used for direct control of equipment by connecting the output of the Remtron relays directly to the equipment, *or* it can be used to control lock machinery via PLCs. Barkley Lock personnel have demonstrated the second option, in which both the Remtron receiver and a rack of PLCs were mounted in a mobile cabinet that can be rolled to locations within the lock's gallery. There the PLCs can be connected to terminal strips for controlling equipment.

Both configurations of onsite wireless control systems have proven to be equally reliable. Each has performed according to the manufacturers' specifications. The use of onsite wireless controls along the lock wall provides the lock operators with an auditory and visual perspective that is not available from inside the local control rooms.

Future applications of this technology under consideration may result in cutting the cost of testing new equipment (e.g., a water level indicator) before it goes on line. In the past, new equipment had to be wired directly to the main PLC drop in order to determine its compatibility with the system. Wireless control and

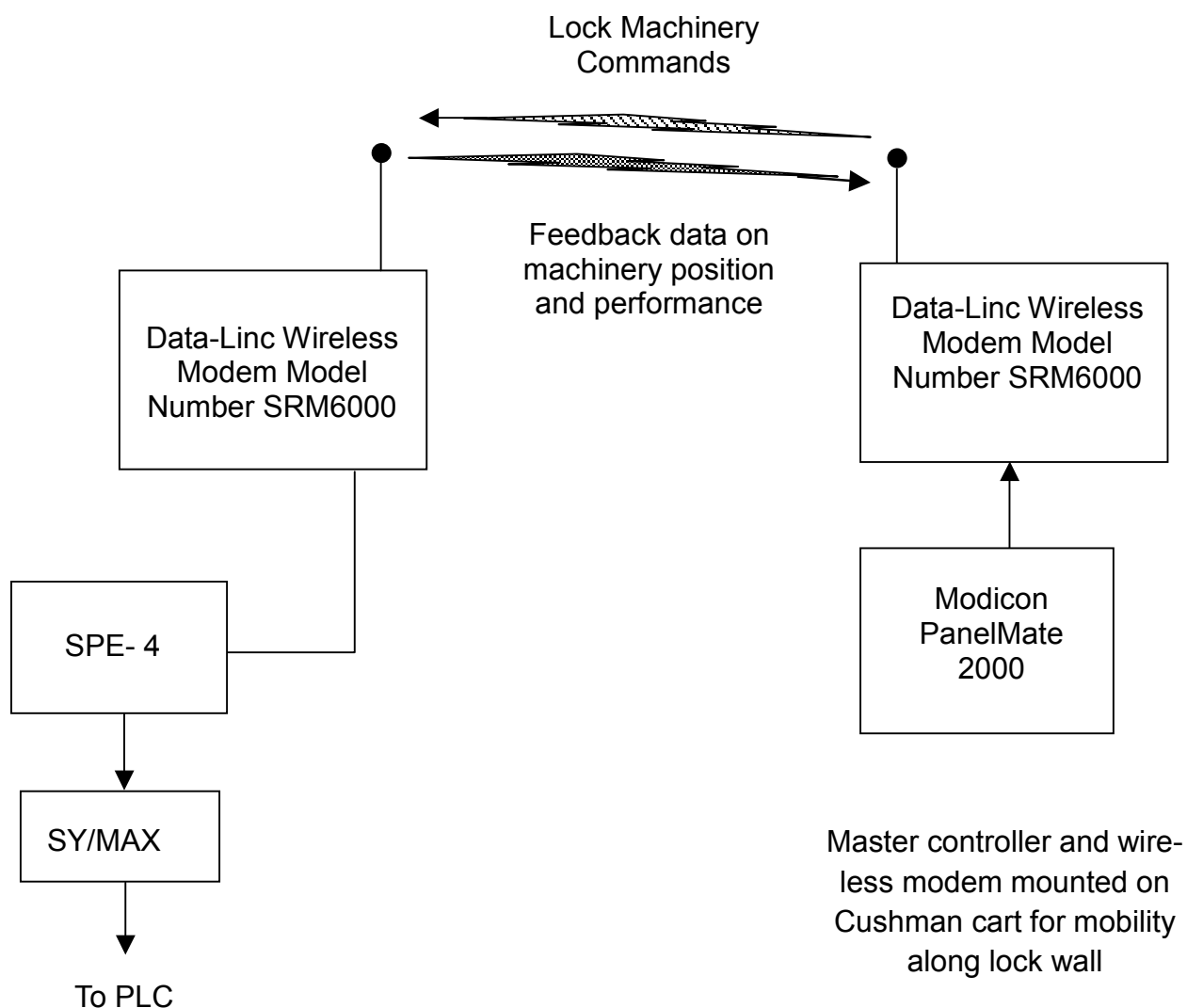
monitoring systems allow circumvention of the traditional wiring as the new, experimental, or temporary equipment can be connected with a temporary wireless system.

References

Remtron, Inc., Radio Remote Control and Telemetry Systems: Command Pro User's Manual; 142108c-CMMDPRO.pm6, Rev C (Remtron, 1999).

SRM 6000 Operating Instructions, Data-Linc Group, Redmond, WA, 1999.

Appendix A: Configuration for Onsite Wireless Control Using the PanelMate/Data-Linc Modem System



Appendix B: Specifications for Modicon PanelMate Plus Series

DISPLAY

- 9" CRT, 256 color, with 8-state PowerBlink
- 9" CRT, 256-level grayscale, with 8-state PowerBlink
- Horizontal Scan Frequency: 31.5 KHz
- Refresh: 60 Hz
- Resolution: 640 X 480 pixels (VGA)
- Dot Pitch: 0.28mm (color)

TOUCHSCREEN

(Touchscreen models only)

- Resistive technology for gloved hand operation
- Resolution: 256 X 256 cells
- Field replaceable touchscreen

OPERATOR ENTRY

(TouchPanel models)

- 5" X 3" cell TouchPanel for control selection
- 0 to 9, •, -, numeric entry keypad
- Four recessed membrane control buttons

(Touchscreen models)

- On-screen, 5 X 3 cell control selection
- Non-overlapping, pop-up on-screen numeric keypad
- Four on-screen control buttons

MOUNTING

- Three-piece modular design
 1. Front panel module
 2. Display module
 3. Electronics module

EXTERNAL CONNECTIONS

- Two serial ports are standard
- Selectable RS422 or RS232C

- 110-38,400 baud
 1. PLC brand-specific protocol communication to PLCs using a PLC BASIC module
 2. PLC brand-specific protocol communication to a host computer using PLC BASIC module
- Connection for an 8 ohm audio output external speaker
- Connection point for external fault annunciation
 1. Form C contact type
 2. 2 amps @ 28 VDC rating or 2 amps @ 240 VDC rating

SYSTEM NEMA CLASS

- Designed for NEMA 4 or NEMA 12 installation when properly mounted in a correspondingly rated enclosure
- Stainless steel option for NEMA 4X installation

PROTECTIVE FRONT PANEL

- Polane® Enamel Paint
- High contrast filter
- Impact-resistant protective cover CRT
- Stainless steel modules available (NEMA 4X)

SYSTEM AMBIENT TEMPERATURE

- Operating: 0 to 50 °C (This operating temperature should be expandable to suit the operating environment where the equipment is being used. The temperature range must be coordinated with the equipment manufacturer prior to procurement.)
- Non-operating: -20 to 65 °C

SYSTEM VIBRATION

- Operating: 10 to 57 Hz at .006" peak-to-peak displacement, 57 to 500 Hz at 1G
- Non-operating: 10 to 57 Hz at .015" peak-to-peak displacement, 57 to 500 Hz at 2.5G

RELATIVE HUMIDITY

- 20 to 90% non-condensing

SYSTEM SHOCK

- Operating: 10G
- Non-operating: 20G

ALTITUDE

- Operating: Sea level to 10,000 feet
- Non-operating: Sea level to 30,000 feet

POWER SUPPLY

- Voltage: 90 to 132 VAC, 180 to 264 VAC
- Frequency: 47 to 63 Hz
- Consumption: 52 watts (grayscale), 72 watts (color)

HEAT OUTPUT

- Grayscale: 52 watts (177.5 Btu/hr)
- Color: 70 watts (239 Btu/hr)

APPROVALS

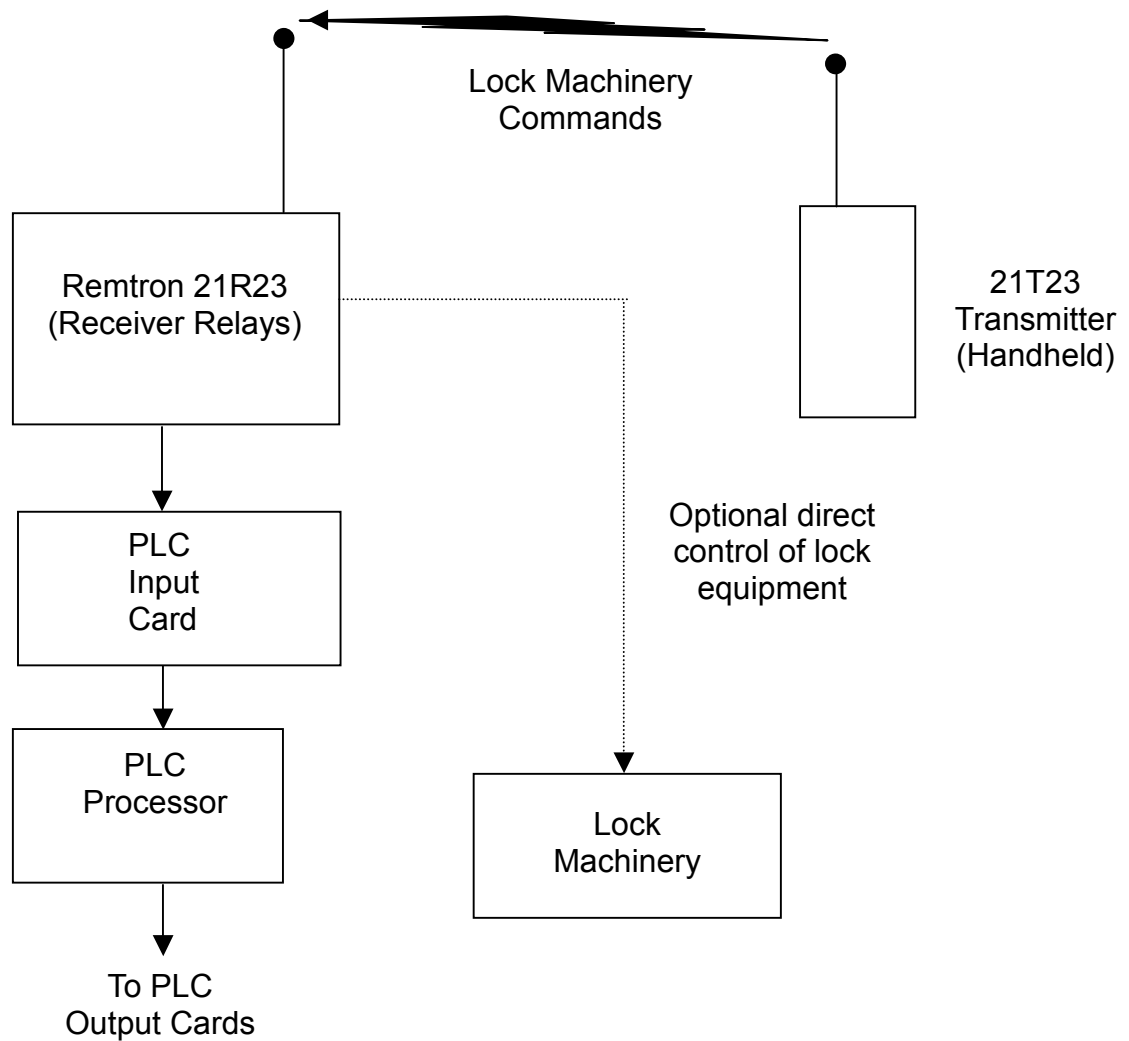
- UL
- CSA
- CE (pending)

Appendix C: Specifications for Wireless Modem Procurement

1. The modems shall operate on spread spectrum bands in the 902-928 MHz frequency range, as frequency hopping modems, and shall provide a range of at least 10 miles of line-of-site communications.
2. No site license shall be required.
3. The modems must be immune to interference problems.
4. The modems shall interface easily with PLCs and PCs.
5. Surge protection circuitry shall be incorporated using voltage clamps and fuses to protect the modems from voltage surges on the power and data lines.
6. Antennas shall be mounted on the modems.
7. The modem's power requirements shall be as follows:
 - 8 to 18 VDC, 180mA transmit mode
 - 100mA receive mode with a standard input of 120 VAC stepped down to 12 VDC via wall transformer with a power consumption of no more than 15 watts.
8. Each modem shall have a DB-9 mating connector.
9. Each modem shall have an operating temperature range of -40 to +75 °C.
10. The dimensions of the metal enclosure of each modem shall be as follows:
 - Length: no greater than 10 inches over mounting flanges
 - Width: no greater than 5 inches
 - Depth: no greater than 1.5 inches
11. Each modem shall have indicators, which show "Power On," "Carrier Detected," "Data In," and "Data Out" of the modem for immediate, clear, and easy confirmation and diagnosis of system operation.
12. Each modem shall be received having been configured at the factory.
13. The modem shall be provided with a User's Guide containing simple and easily followed directions for changing configuration in the field.
14. Two (2) modems shall be configured to communicate electronically with the Square D Modicon PanelMate-1000 control unit in full duplex mode, operating as a "master."
15. A cable of at least three (3) feet but no more than six (6) feet in length shall be provided to connect each modem electronically with the Modicon PanelMate.
16. These same two (2) "master" modems shall be capable of transmitting and receiving 4-wire electronic signals with the following characteristics:

- Receive plus (+)
 - Receive minus (-)
 - Transmit plus (+)
 - Transmit minus (-)
 - 8 bits
 - 1 stop
 - even parity
 - 9600 baud rate
 - RS422 data interface
17. Two (2) modems shall be configured to operate as “remotes” and shall have RS-422 data interfaces in order to send commands and receive data from Square D 8030 Series SY/MAX PLCs.
18. The modems shall be Year 2000 (Y2K) compliant.

Appendix D: Configuration for Onsite Wireless Control Using Remtron System With Handheld Transmitter



Appendix E: Specifications for Remtron Control System Procurement

1. A control system is required for operation of electrical/mechanical equipment used at navigation locks. The remote radio control system shall be configured to provide input to programmable logic controllers (PLCs).
2. The radio system shall be FCC-license free. The radio system shall comprise a control transmitter and a control receiver capable of operating on any of eighty-seven (87) radio frequency (RF) channels on the 900 MHz band and capable of any one of over 64,000 security addresses. The radio system shall operate over a range of at least eight hundred (800) feet.
3. The control transmitter and control receiver radio system shall have special programming as follows:

The control receiver relays shall be designed for operating PLCs. One control receiver relay shall be closed if the communications link is operating. This relay path shall be opened if the radio link is faulty for reasons including loss of radio signal, dead battery, out of radio range, or an electronics fault.

4. The control transmitter shall have nine (9) rocker switches, and five (5) pushbutton switches. The pushbutton switches will be: (1) power ON/2nd functions, (2) power OFF/ESTOP functions, (3) SELECT "UP" or "DOWN" functions, (4) an "H" function, and (5) an "S" function. All switches shall be contained under an elastomeric (silicone rubber) keypad in a rugged impact resistant case. The control transmitter shall include a self-test and battery status light emitting diode (LED), an internal antenna, three (3) AA alkaline batteries. The control transmitter shall be configured to operate for one hundred (100) hours on the AA batteries. The transmitter shall include a leather holster suitable to operate the transmitter in the hand or from a belt loop. The transmitter shall also include a shoulder strap. A water resistant bag for carrying the control transmitter shall be included.
5. The control transmitter shall have a SELECT pushbutton to choose between "UP" and "DOWN" outputs. An LED shall be linked to one of the control receiver

relays. This control receiver relay will remain latched in the last commanded position. This relay shall be capable of notifying the PLC relay to which it is interfaced that the other relay outputs correspond to either UP or DOWN commands. The relay shall be released if the control transmitter OFF/ESTOP is pressed. The LED shall be illuminated when the DOWN function is selected, and shall be dark when the UP function is selected. The LED shall become dark if the transmitter OFF/ESTOP is pressed.

6. The control transmitter shall power itself to OFF automatically if no faceplate buttons or switches are depressed for 59 minutes.

7. Additional control transmitter specifications:

- Size: not to exceed 12-in. (length) X 4-in. (width) X 1.5-in. (thickness)
- Weight: less than two (2) pounds
- Case material: nylon-based molded plastic

8. The control receiver shall have thirty (30) user control relays plus two (2) safety interlocks. The control receiver shall operate from a 115-volt AC power supply. All electrical connections shall be via terminal strips. The electronics shall be housed in a National Electronics Manufacturers Association (NEMA) 12 steel enclosure. Twenty-nine (29) receiver relay outputs shall be momentary. One (1) receiver relay corresponding to the transmitter UP/DOWN SELECT function shall be latching. The control receiver antenna shall be an outdoor 5 dB gain omni-directional type that mounts atop a facility-provided nominal 1.5-in. diameter vertical standing pipe. The antenna itself is approximately 32-in. high and includes the mounting bracket to attach the pipe. Also included is 15 feet of low-loss coaxial cable to connect this outside antenna to the indoor control receiver.

9. The control receiver ESTOP relay shall be activated when the control transmitter ON switch is pressed. This relay shall only be released under the following conditions:

- The receiver power is removed (or removed and restored).
- The transmitter ESTOP pushbutton is pressed momentarily.

10. A loss of radio link (momentary or permanently) shall not release the ESTOP relay at the control receiver.

11. Pressing the ON/2nd button on the control transmitter shall activate a separate relay on the control receiver, which shall have the capability of being associated with a separate slow/fast function for each of the nine (9) rocker switches. The ON/2nd control shall be configured so that the ON/2nd button must be pressed

simultaneously with the selected rocker switch for which the “2nd” function is desired.

12. Additional control receiver specifications are as follows:

- Control Receiver is intended for wall mounting via four (4) bolts (not included). All electrical connections to/from the PLC and for receiver input power are via terminal strips. The RF output connection is via a coaxial cable fitting already attached to the enclosure.
- 22 user control relays (discrete commands-momentary)
NOTE: option relays must be configured as *latching* if the system is interfaced to directly control lock machinery without the aid of a PLC
- 2 safety interlocks (latching)
- 8 analog relays
- NEMA 12 steel enclosure
- 5 dB omni-directional flexible mount antenna – 32-in.
- Type N male connectors
- Belden Coaxial Cable
- Size not to exceed 12-in. (length) X 12-in. (width) X 6-in. (thickness)
- No more than 25 lb
- 115 VAC

Appendix F: Review Comments From Barkley Lock Personnel

Memo For Records

To: Dave Stephenson

From: Barkley Lock, Gerald Cunningham

Subject: Review of Technical Report INP-114

The major objective to demonstrate wireless command, control, and monitoring of lock equipment was met. Even though we have tested the remote for almost two years we still have not put it into operation full time. After we met our objectives we continued to design and develop the technology to incorporate the remote into the newly purchased PLC equipment. We are in the process of upgrading our Lock controls. During the test period we were successful in operating the lock safely with the panel mate from any position on top of the lock wall with 100% accuracy. The remote system did not fail on any operation. The lock operators that tested the remote could actually be on the lock wall where the action is taking place and view the operating area to allow for a safer operation. Barkley Lock is a high lift lock, normal lift being 57' and is 800' X 110' wide. Our vertical viewing distance from the top of the wall to the bottom of the chamber is approx. 80'. This presents an impedance to the operator that is trying to operate from the control stand. His view of the operating area is limited even when using closed circuit cameras. The panel mate installed on the Cushman cart provided them with a safer means to check for obstructions before operating equipment, watch barge movement while operating equipment, and handle any emergencies that may have arose. It positions the operator next to the equipment where he/she can hear any unusual noises that might be coming from the equipment and take quick action to shut the equipment down before a major malfunction could occur. The Remtron unit also provides us with similar operation but it has no feedback as far as position of equipment or any interlock features. The range is limited to line of sight on the Remtron. It is only used when performing maintenance on equipment when any movement is critical for employee safety and the lock operator can be positioned right next to the equipment

being operated. Both units can be operated from inside the gallery's if you are positioned next to the equipment.

Barkley Lock, along with all locks in the Nashville District, has only one operator per shift and has operated under this arrangement for over 30 years. While the operator travels from one end of the lock to the other to operate he/she can control the lock at any desired location on the lock wall and stop the locking for any unsafe condition that might warrant a shutdown. They can observe both sides of the lock gates for any obstruction and operate the equipment for a known safer operation.

Many thanks goes out to Jerry Wisdom, Electrician at Barkley Lock, and Richard Nimmo, Mechanical Engineer, Nashville District, for all the hard work that was put into the wireless remote. The design, development, programming and installation of the equipment was accomplished by this team. And to our friends from CERL, Dave Stephenson, Ashok Kumar, and Patrick Wilson, we extend our thanks for a great partnership and finding the funds to demonstrate this project.

My personal thanks is extended to Wayne Lanier, Operations Manager, West Ky. Area for allowing us to participate in this wonderful project.

FROM: Wisdom, Jerry D CELRN-CO-WKY/A-BAR/L
TIME: Thursday, March 22, 2001 07:12
TO: Cunningham, Gerald B CELRN-CO-WKY/A-BAR/L
SUBJECT: FW: Review of technical report INP-114, Wireless control

Gerald, Special appreciation is extended to you as well as Wayne Lainer, Dr. David Stephenson, Patrick Wilson, and Dr. Ashok Kumar for allowing me to be a part of this INP Research program. At this time I would like to say that the "On Site Wireless Control of Lock Operating Machinery" objectives of applications were met. Lock maintenance applications with the radio remote allows for increased efficiency and utilization of time as pertains to troubleshooting and repair of systems that requires personnel to be in different locations at the same time due to direct feedback capabilities with some radio remote applications. Barkley lock project is considered to be a high lift lock. Normal lift is 57 feet. We only have one Operator on shift at any given point in time. Tow haulage operations on the lower pool elevation requires the Operators to leave the existing control stand in order to maintain visual contact with the towline and deckhands from start of exit to end of exit for safety reasons. Barkley lock has a hardwired outside control station with a portable control unit so the Operators can relocate for this reason. Radio remote increases the range and mobility thus improving safety with some increase in expenditures. Technology continues to improve and Nashville District, Barkley lock will continue to assist research and development for better ways of monitoring equipment, improving safety, decrease fatigue and stress on personnel and most of all maintain the highest level of professional service for our customers.

Sincerely
Jerry Wisdom
Lock & Dam Equipment Mec.
Barkley Lock
Nashville District

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14. ABSTRACT The operational capabilities of navigation locks, especially those using programmable logic controllers (PLCs), can be further enhanced by the implementation of onsite wireless control of lock operating machinery and systems using either a portable transmitter/receiver system or modems interfaced to a mobile control panel. In essence, the entire lock can be operated via onsite wireless control. Onsite wireless control provides the opportunity for lock personnel to operate the locks outside of the control room. This added mobility enables operators to better position themselves to see and hear what is happening during lockage operations. Furthermore, some lock operations (such as tow haulage) can be accomplished more safely than when confined to operating from a control room.					
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